Report of Panel **5**

Long Range Plan

National Library of Medicine

Assisting Health Professions Education Through Information Technology

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Panel 5

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Contents

1 Background and Context

Panel Five had as a topic assisting health professions education through information technology. The Panel was charged with considering the issue of how information technology might be used to promote and facilitate the education of health professionals to meet the needs of the 21st century.

"Information technology" may be broadly defined as encompassing the full range of computer-based aids to learning, including computer-assisted instruction, case simulations, bibliographic retrieval systems, electronic textbooks and knowledge-base systems, self-testing and appraisal programs, and personal file management tools.

The American systems of health care and of education of health professionals are considered among the best in the world. By and large, our professional schools produce knowledgeable, compassionate, responsible, and technically competent individuals. Why, then, should there be any concern with the content and methods of education of health professionals?

Knowledge Base of Health Sciences

Within the last few decades, powerful forces have radically changed the scope and complexity of the health sciences and the delivery of health care. These forces are continuing to influence the shape of health care, increasing and altering the body of medical knowledge, changing the way health professionals practice their craft, and modifying the system of health-care delivery.

It can be argued that we are in the beginning stages of a new age of health care. Recent advances in medicine, particularly in molecular and cell biology, immunology, and neurobiology, have opened new paths to preventive, diagnostic, and curative strategies of astonishing power and subtlety. Progress in the fields of dentistry, nursing, pharmacy, and other health professions have yielded new strategies for maintaining health and dealing with illness.

This explosion of knowledge has combined with multiple factors to change the way that health professionals function today. The aging of the population, the shift from acute illness toward chronic disease, the emphasis on cost containment, the increasingly corporate nature of health-care delivery, and the availability of information-processing technology are all exerting powerful influences. These factors will surely alter even more radically the way that health professionals of the 21st century practice.

One obvious effect of the expanded knowledge base is that any single individual can master only a decreasing fraction of the total spectrum of the available information. As a result, there has been a rapid growth in the number of health disciplines, and of specialties within disciplines. This has produced an increasingly fragmented clinical practice.

Education of Health Professionals

Despite these major advances in the science and technology of health care, as well as the new challenges to the field, the education of health professionals remains grounded in the past. The methods used to train physicians, for example, differ little today from those of a half-century ago. For all of the health disciplines, the structure of education still primarily consists of lectures, in which a procession of teachers relates large quantities of scientific material to a passive student audience. Current methods of instruction in the health sciences cannot meet the challenge of the exponentially increasing flow of new discoveries.

The explosion in medical knowledge has placed impossible time demands on the curriculum, and has far outstripped the ability of our students to memorize, let alone retain, the quantity and complexity of scientific knowledge. Despite exhortations from many national organizations in the private and public sectors, the trend toward narrow specialization continues to increase, and the duration of professional education, particularly at the graduate level, tends to lengthen. We cannot depend on traditional continuing education to fill this gap.

Traditional continuing education consists of general reading, attending courses, and informally discussing medicine with colleagues. It helps keep medical practitioners abreast of the state of the art as viewed by medical experts. The goals of traditional continuing education, however, are often diffuse, diverse, and may not be directly applicable to practice.

Traditional continuing education may be only the tip of an iceberg of possibilities
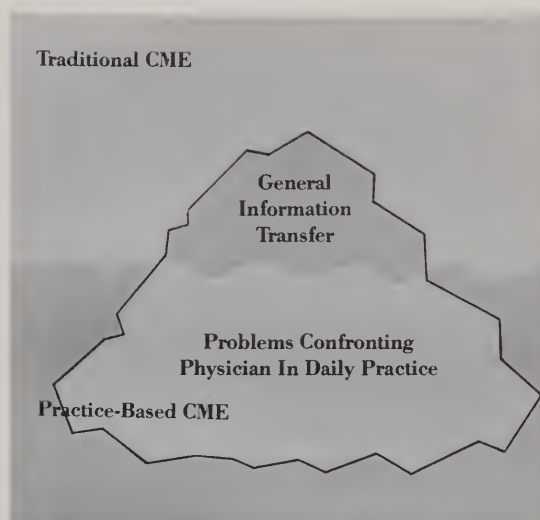
for effective learning (see figure). The body of the iceberg, which encompasses learning from real events in practice, offers many more possibilities. The next decade will bring advances in methods that will permit linking education more directly to actual patient problems.

The new continuing education, made possible by the computer and current telecommunication technologies, will be more individualized and better related to practice.[1] Refinements of existing software and the development of methods to implement the new continuing education in practice are required to achieve maximum benefit.

Information Technology and Health Sciences Education

One very promising response to the problem of information overload is to take advantage of information technology to facilitate learning and to provide easy access to appropriate information sources for the practicing health professional at the time and place most needed. Computer-based educational applications can help these professionals acquire essential knowledge and master problem-solving skills. Comprehensive training and experience with modern methods of infor-

7

mation management during the students' formative years will greatly enhance their effective functioning as health-care practitioners and professionals committed to lifelong learning.

In emphasizing the importance of information technology in the education of the health professional, we recognize the inherent tension between the changing and unchangeable aspects of health care. Information technology has the potential to address the ever-changing and ever-broadening mass of knowledge concerning the etiology, prevention, and treatment of disease, as well as the maintenance of health. This use of technology, however important, must not distract from the fundamental human aspect of care: the relationship of an individual health professional to an individual patient.

The role of information technology includes the teaching of content, but even more important, concerns the method of education. Students should be given fewer answers and more tools—tools for self-teaching and for synthesizing, framing, and revising knowledge. They should have the opportunity to practice, from the earliest days of professional education, skills of seeking out information, testing hypotheses, and solving problems. The underlying objective in the use of information tech-

nology in health sciences education is not so much the transfer of current information, but more importantly, providing an environment that encourages the student to take increasing responsibility to become an independent learner, with emphasis upon understanding and application of knowledge.

The use of information technology in health sciences education is not new. Significant advances have occurred since the early applications of drill-and-practice, computer-aided instruction two decades ago, and a number of institutions have developed prototype projects in the use of information technology in health sciences education. Advances in the educational applications of information technology have been made possible by a number of factors: improved understanding of the learning process and of the potential roles for the use of computer technology; more detailed specification of the information requirements in the academic and clinical settings; more powerful tools for creating computer programs; and advances in technology that were undreamed of 20 years ago. As a result, there are now very useful applications that support bibliographic retrieval, education, information management, and clinical decision making.

Examples of Innovation in Use of Information Technology in Education

Various medical and nursing schools have been pioneers in the application of information technology in the education of health professionals. Ohio State has had a major computer-based medical educational emphasis some for years. Other schools such as the University of Illinois, Cornell, Georgetown, the University of Washington, Dartmouth, and Massachusetts General Hospital have made significant innovations in the educational applications of computer technology.[2]

Perhaps the most novel experiment at present is a new curriculum at Harvard Medical School that involves a basic restructuring of medical education. This program (referred to as the New Pathway) emphasizes problem solving and independent learning. A major element of the new curriculum is the use of the computer as an integral tool for education and information management.[3] Each student and faculty member has a personal computer workstation connected to a communications network and a central computer data base. Basic tools such as electronic mail, word processing, and personal filing systems are all parts of the program. Computer applications also include bibliographic retrieval access, self-teaching and self-assessment modules, simulations of biological systems, and patient simulations. The intent is to graduate students who have developed skills in managing their own learning and are capable of utilizing information technology for the management of scientific and clinical information, clinical practice, and continuing education.

The IAIMS (Integrated Academic Information Management System) initiative taken by NLM is an important model of how the Library can initiate change. Initially, IAIMS was defined as a planning and development effort for establishing an institution-wide computer-based integrated information system and a new role for health science librarians.[4] The IAIMS sites are now evolving to become multidisciplinary centers that bring together experts in medical informatics, knowledge organization, library science, decision-assistance systems, education, and health-care administration. Through IAIMS, NLM is fostering dynamic, real-world laboratories for dealing with the broad issues of health-care information management.

Examples of Computer-Based Education Programs

The increasing interest in the development of clinical decision-assistance programs offers a major opportunity for applications of information technology that complement the more traditional modes of medical education. These programs range in complexity from simple "IF–THEN" rules, which remind clinicians in cases where prespecified protocols are violated, to programs that are at the forefront of artificial intelligence research and whose performance can rival expert clinicians in well-specified, limited challenges.[5][6][7][8][9] One of the more exciting aspects of this research is the range of new insights that are being provided into the nature and process of clinical reasoning.

Another promising application of computer technology in medical education is the simulation of complex biological systems. Prototype computer-based simulations can facilitate the introduction of clinical medicine to the student and may include the simultaneous interaction of a number of variables and closed-loop feedback control. These programs use methods that range from simple random assignment of patient "states" (such as the value of the blood sugar in a simulation of diabetic ketoacidosis) to complex modeling of physiological systems such as cardiovascular regulation.[10][11] Coupling these models with high-resolution graphic displays and computer-controlled video disk presentations greatly enhances the teaching potential.[12]

Bibliographic Retrieval

NLM has been a pioneer in promoting easy and inexpensive access to the published literature. The advances made possible in bibliographic retrieval by NLM have affected more members of the health-care community than any other single application of information technology. The development of the MeSH (Medical Subject Headings) indexing system and the MEDLARS (Medical Literature Analysis and Retrieval System) accessing system have contributed enormously to the advancement of education at all levels and in all settings—undergraduate, research, and practice. Decreasing cost and increasing availability of personal computers, together with reasonably priced MEDLARS services, have placed online bibliographic assistance within the reach of the average practitioner and brought closer the goal of each professional having ready access to any desired medical knowledge independent of the time and place of need.

Knowledge Management

NLM has been one of the most important institutions in making information readily available to the health science professional. Although in the past, this role has been considered to be primarily one of storage, indexing, and retrieval of paper documents, it is both relevant and timely for NLM to assume a more dynamic role in terms of knowledge management.

Knowledge management may be defined as a set of methods for the acquisition, organization, and maintenance of a knowledge base to facilitate retrieval of specific information. Depending on the specific application defined, the user of the knowledge may be a clinician, a student, a researcher, an educator, or an administrator.

The knowledge maintained by a knowledge-management system may be of two general types. The first is a conceptual framework or schema that defines organization and relationships within domains of knowledge. NLM's MeSH vocabulary is one example of an organizational framework: the hierarchical organization of the MeSH terms defines an explicit relation among the different terms in the nomenclature.

The second type of knowledge-management system provides access to content knowledge in either structured or unstructured form. Structured knowledge is information stored in a form that can be easily accessed by key ideas or concepts. In a book the chapter headings and index represent a primitive form of structured knowledge. Much more sophisticated examples of structured content are electronic textbooks such as the Hepatitis Knowledge Base which was the subject of active experimentation by NLM.[13] Structured knowledge can also exist in the form of procedures or methods for accomplishing specific tasks. Unstructured content, on the other hand, includes narrative text found in traditional textbooks and in the archival journal literature, as well as pictures, graphs, and other forms.

Developments in Computer Technology

After a slow start, developments in computer and communications technology have proceeded at an astounding pace in recent years and show no sign of slowing down. There is general optimism that even the most ambitious potential applications of information technology to education in the health professions will soon become both technically feasible and economically possible.

At the present time, available technology enables routine data collection; information storage, manipulation, and display; and a variety of forms of automated record keeping. In many settings, students, faculty, and practicing physicians have access to convenient, compact, and powerful personal computers. Network communication between individual workstations and institutional computer resources is becoming less expensive and more versatile. Powerful, easy-to-use authoring languages make it easier for the programming novice to create exciting educational programs for the health professional. The display of information is becoming increasingly effective with higher resolution graphics and the use of color.

Radically new forms of user interaction are made possible by innovations such as "pull-down windows" and various types of pointer devices (the "mouse" being one popular example.) Computer-controlled video disks allow easy manipulation and display of either still images or scenes with coordinated sound and motion.

These developments represent the technology of the present; to try to predict the possible technologies of the future is extremely difficult. It is safe to predict, however, that there will be much more powerful, smaller, and less expensive computers, with graphic displays of much higher resolution and much better communication capabilities. The limiting factor of educational applications for the health professional will not be primarily hardware, but rather a paucity of easily available and appropriate applications.

Future Role for NLM

This report outlines a vision of the future and details several windows of opportunity for attaining this vision. We strongly support the view that, indeed, there are real and exciting potential applications of information technology that can revolutionize the education of health professionals. Indeed, some of the most critical weaknesses of present health sciences education, and more importantly, some of the most important opportunities for the future, can only be met through the imaginative and comprehensive use of information technology. NLM has had a dynamic role in the past in facilitating the storage and dissemination of medical knowledge. This Panel is deeply persuaded that in the future, the role of NLM can be even more important in supporting the application of the full range of information technology to the education of the student in health sciences and to the support of the practicing health professional.

NLM Programs and Recent Accomplishments

Historical Role of NLM

Through the years, NLM has been involved in various ways in assisting health professionals in carrying out their responsibilities as educators and enhancing the environments for learning by students in the health professions. Historically, these activities have been carried out intramurally by the LHNCBC (Lister Hill National Center for Biomedical Communications) and the NMAC (National Medical Audiovisual Center), which in 1983 was officially merged with the Lister Hill Center. Extramural support to the health professional community has been provided by the Library's Extramural Grants and Contracts Program.

Mission of the Lister Hill National Center for Biomedical Communications

First established in 1969 as the research and development arm of NLM, the Lister Hill Center's organizational mission is closely tied to the goal of assisting health professions education through the timely and efficient exploitation of new information technologies. The Lister Hill Center's annual budget in FY1986 was $9.042 million. Specifically, the Center:

- performs research and development to create and improve biomedical communications systems, methods, and networks to enhance information dissemination and utilization among health professionals;

- collaborates with members of the health professions community and studies, defines, and develops needed information technology materials and services;
- develops audiovisual and other information systems to improve health professions education, research, and the delivery of health services;
- encourages and performs research and development in the production, dissemination, use, and evaluation of audiovisual, computer-based, and other educational materials and systems;
- trains health educators in methods and technologies supporting biomedical communications; and
- plans and administers a national program to improve the quality and the use of biomedical and audiovisual materials in schools of the health professions and the biomedical community.

Mission of the Extramural Grants and Contracts Program

NLM's Extramural Programs, authorized by the MLA Act (Medical Library Assistance Act of 1965) and its extensions, support improvements in health information services and biomedical communications by providing grants to develop and extend library services, strengthen information resources, conduct research in ways of improving communication and knowledge transfer, train health information personnel, and produce critical reviews and other publications on important health topics.

During FY1986, awards totaling $2.347 million were made for 37 new grants, and $9.545 million for 62 continuing grants supporting activities begun in prior years.

In addition, contracts provide for a national network of RML (Regional Medical Libraries) with the necessary resources and services to give backup support for local health science libraries. In particular, the RML Network is an important agency in organizing activities leading to computer literacy among health professionals. It promotes habits relative to the access and use of data bases and health-related literature, which tend to lay the groundwork for lifelong learning; it is an outlet for acquainting health professionals with new hardware and (interactive) software; and it helps to stimulate an awareness of pertinent NLM programs and products.

Intramural Activities of the Lister Hill Center

The TIME (Technological Innovations in Medical Education) Project was begun in late 1983. The primary goal of TIME is to address the potential application of the new technologies of microprocessor, interactive video disk and speech recognition to the education of health professionals. The new techniques offer unprecedented capabilities for interactive and visual presentations of educational material. The TIME Project is exploring these capabilities by developing a series of problem-based patient-related clinical simulations.

With planning begun in 1984, the National Learning and Demonstration Center is to provide an environment and demonstration site for state-of-the-art technologies in computer-based education in the health sciences. The Center will allow health science educators to have access to a spectrum of computer-based educational materials. In addition to offering demonstrations, the Center will serve as a laboratory for comparative studies and evaluation of such materials.

Begun in 1982, the Computer-Assisted Curriculum Delivery Program consists of a series of experiments utilizing video disk and microcomputer technology. Through collaboration with relevant professional societies, prototype disks under microcomputer control have been produced in radiology, pathology, and most recently, orthopedic surgery. Studies are currently underway to assess the value of these tools in a variety of educational settings.

In 1985, NLM staff, including research staff from the Lister Hill Center, examined the feasibility of developing a Unified Medical Language System. This examination revealed that the technology and knowledge needed to support the research and development of such a system are now, for the first time, becoming available, and that this fundamental problem in medical informatics can be successfully addressed under NLM leadership. With substantial resource support secured for 1986, NLM has launched this effort, which will seek to link the vocabulary used to access the basic science and clinical literatures to the vocabulary used in clinical practice for the recording of patient records, in health science education, and in health-care administration.

Extramural Programs of NLM

The NLM's grants and contracts activities consist of the following programmatic areas that support health professions education:

- Research Grants support investigations of the generation, organization, and utilization of health knowledge. At the Latter Day Saints Hospital-Deseret Foundation in Salt Lake City, for example, a project is underway to assist physicians to draw upon medical knowledge through computer-based decision logic.
- Medical Informatics Research and Training Program encourages research into fundamental issues of health knowledge, including the impact of advanced computer and communications technology on knowledge representation systems. Besides the usual investigator-initiated research grants, there are New Investigator Research Awards and Research Career Development Awards for promising younger scientists.
- Medical Library Resource Grants are of two types. The Resource Improvement Grant assists single institutions and consortia in developing basic collections. The Resource Project Grant is directed toward established health science libraries and enables them to undertake new services or expand existing ones. At the Dahlgren Memorial Library of Georgetown University Medical Center, for example, a library computer information service is being established to provide a learning laboratory environment where students, faculty and staff may obtain guidance in the use of microcomputers and in data base development.

- The IAIMS Program follows an NLM-
supported study by the Association of
American Medical Colleges that identi-
fied the need for academic health
science centers and hospitals to take
immediate steps to use new information
technologies to facilitate the flow of
recorded biomedical knowledge through-
out the institution in as direct and use-
ful a form as possible. The study
recommended the development of proto-
type network systems, as well as pro-
grams that encourage the rapid integra-
tion of information technologies in the
learning and practice of the health
professions. In response to the study's
recommendations, NLM launched the
IAIMS Program, which uses computer
and communications technologies to
bring together operational and aca-
demic information in support of health
research, education, patient care, and
management. At the present time, some
eight institutions have IAIMS planning
or implementation awards.

3 A Vision of the Future

The teaching and learning environment for health professionals will have changed considerably in the year 2006. The centers of excellence and IAIMS will produce widely adapted curriculum models for integrating technology into the teaching and learning process. The educational emphasis in the 21st century will be primarily on individual and small-group interactions, supplemented only occasionally by traditional lectures to large groups. The focus of professional education in all the health science curricula will be on training students in problem solving, critical thinking, and analytical skills. There will be equal emphasis on helping the student gain experience in how to use technology for acquiring, storing, and managing information.

Computer-based patient simulations will be used extensively to facilitate the student's acquisition of skills in clinical problem solving; to help the student learn to deal with the inherent uncertainty, ambiguities, and contradictions in clinical data; and to challenge the student to learn how to collect and interpret data in the most efficient fashion. All of the computer-based learning activities will be available to the student at any time and from the most convenient location, whether it be within or remote from the institution.

In contrast to the present, much less curricular time will be spent on delivering purely factual information. Students will become highly skilled in retrieving pertinent information from computer-stored data banks for particular educational issues or specific clinical problems. Teachers will routinely use information technologies and computer simulations, including high-resolution graphics, animation, and video images, to challenge students during the development of their basic science laboratory and clinical patient-care skills. The capacity to evaluate student performance will be greatly enhanced by new techniques that focus on problem solving rather than on short-term memory recall. Electronic mail will be widely used in information transfer and information sharing among the students and between the students and faculty. Electronic networks make it possible for the students and faculty to engage in a continuing dialogue in an "intellectual network" of frequent communication, questioning, and sharing.

Extramural evaluation programs for purposes of licensure, specialty certification, recertification, and other forms of credentialing will be accomplished using computer and other advanced technologies to assess educational achievement, diagnostic acumen, management skills, problem solving, decision making, and other measurable aspects of professional competence. These new technologies will have completely replaced traditional paper-and-pencil testing for credentialing in the health professions. The introduction of computer-based technology as the evaluation methodology for licensure and certification will have a profound influence on the speed with which the educational system introduces similar technology for both education and intramural evaluation.

Integrated information systems in regional medical libraries, in academic medical centers, and at NLM will permit faculty to draw liberally from local, regional, and national computer-based resources in developing their curricular offerings. The world's biomedical literature will be easily available in computer-stored books and journals, and a wide variety of knowledge bases, visual images, and expert systems will reside in multiple national computer-stored data banks that may be accessed at any time by a few keystrokes, from any location. The different professional societies and medical publishing organizations will have adopted a Unified Medical Language System for indexing and abstracting to make the different information sources more readily available via automated retrieval systems. Extensive development in computer-assisted knowledge management, using the unified language as a conceptual framework, will guide the information seeker in taking advantage of these resources.

There will be a substantial cadre of well-trained library, information, and health science specialists who are trained by the academic departments and training programs sponsored by NLM. Many faculty will have been trained by NLM-sponsored faculty development programs; they will have made significant contributions to the development of computer-based educational programs and expert systems. These programs will be made available through NLM resources, published by medical publishing firms, or circulated through consortia of professional schools. The programs will be indexed in standard literature reference files and routinely cited in the literature. These contributions to computer-based educational materials are seriously considered in the faculty reward system and the faculty promotion process.

NLM will have encouraged the development of operational medical information systems that combine and integrate a number of important information management resources, including support for the recording of clinical information in routine care, access to appropriate knowledge resources and continuing education programs, and routine quality-assurance capabilities. Clinical data are recorded by health-care personnel using computer-supported interactive dialogue and the Unified Medical Language System. The successful development of this language

will have evolved through a long period of collaboration between NLM, the NLM-supported centers of excellence and IAIMS programs, academic investigators, medical librarians, professional societies, medical publishers, certification boards, and the insurance industry. The use of a Unified Medical Language System in the operational medical information systems permits the integration of the descriptors used in health records, the diagnostic terms required for reimbursement, and the textual description of scientific conclusions in the medical literature.

Computer-based continuing education programs will have been developed as part of an overall scheme to provide information-management resources to practicing professionals in all of the different health professions. NLM will have made major progress in assuring that such programs are fully available to the practicing health professional, making a reality of the concept of "lifelong learning" and the "continuum of medical education." The knowledge-management systems and expert consultation resources that assisted the practitioner's learning process during the student years will become an indispensable tool throughout his or her career as a practicing health professional. Extensive communication networks will provide the capability for easy and rapid electronic consultation and sharing of clinical information between different professionals. Personal computers and communication networks will provide access to online data bases, knowledge bases, and expert consultant services. The ready and early availability of research findings, together with automated access to a huge pool of data on health and disease of a large population through computer-stored data banks, will permit great strides in describing disease states, identifying causes of disease, and selecting optimal treatments. The value of information in these data banks will have been greatly enhanced through the widespread adoption of a system of recording clinical information using the Unified Medical Language System.

Major Issues and Future Directions

It became evident during the course of the deliberations of this Panel that the subject of information technology in the education of health professionals is both broad and complex.

For many years, the limitations of the technology (e.g., expense, unreliability, difficulty of use), prevented both clinicians and educators from transferring even routine tasks to the computer. The technology has developed dramatically in recent years, and we now find that the major problem is lack of applications and methods of dissemination to take full advantage of current capabilities.

It also became obvious to us that certain aspects of the application of the technology will need to be expanded even further to meet the needs of tomorrow. Without proper expertise and organizational resources, this Nation will jeopardize the quality of education and practice of its health-care providers, and consequently, the quality of its health care.

Our deliberations narrowed to four areas that seem fundamental to assisting future education in the health professions through information technology. These four areas are: the Unified Medical Language System, centers of excellence in health sciences informatics, knowledge management systems for practicing health professionals and students, and educational technology itself.

The first two are necessary prerequisites to exploiting today's technological capabilities, and are vital to meeting future needs. The last two push the boundaries of today's capabilities; they pave the way for providing the environment that will be needed for the health-care community of 2006.

Unified Medical Language System

Current Situation and Needs

A major impediment to widespread adoption of computer-based information systems in health care has been the absence of a standard vocabulary for describing health-care phenomena pertaining to patient care, results of biomedical research, and the managerial and business transactions of ambulatory care and hospital activities. Each vocabulary has evolved separately from noncommon origins: clinical from direct observation of signs and symptoms; research from basic biology and chemistry; and managerial from accounting and business.

In order to integrate computer-based information systems in the health sciences, the vocabulary used in the clinical setting must be linked to that used for indexing scientific, clinical, and behavioral literature; this vocabulary must also be compatible with the terminology used in health science education, in health-care administration, in medical reimbursement, and in health-related social and engineering disciplines.

At the same time, the increasing use of automated information systems increases the need for common terminology. A major resource commitment will be required to develop methods wherein a unified language can be easily used in a professionally acceptable fashion in all the health disciplines. Leadership will be required to overcome habitual recording practices that do not consider integrated uses of documents.

A major accomplishment in the development of a unified medical vocabulary is the worldwide adoption of NLM MEDLARS (based on the MeSH indexing system) for access to bibliographic citations of scientific literature. NLM and professional librarians in schools and hospitals have exerted considerable leadership in developing extensions and enhancements to the MeSH vocabulary and in promoting the use of this example of a standardized vocabulary. However, MeSH is insufficiently detailed for use in clinical care, specialty areas, and many of the health professions outside of medicine.

Windows of Opportunity

Professional groups, academic organizations, librarians, academic investigators, and medical publishers have increasingly recognized the need for common terminology and are growing more interested in collaborating to develop such a common terminology. The proposed NLM centers of excellence and the IAIMS Programs should provide excellent opportunities to collaborate in projects aimed at the incremental development and evaluation of a common language for the different disciplines, professional schools, clinical-classification needs, and reimbursement requirements.

Improvements in computer technology provide new methodologies for research into the language used for all facets of health care. For example, it is now possible to retrieve entire documents and to search and analyze the full text of documents and reference files. This creates an opportunity to undertake a comprehensive definition of the vocabularies and terms used in the different clinical areas, to examine the role of syntax and context in determining the meaning of the terms used in any vocabulary, and to discover methods of language unification or linkage.

Developments in computer-based patient record systems in a number of academic centers have made it possible to assemble large collections of computer-stored medical records. Much of the data in these computer-stored records exists in the form of predefined, controlled vocabularies or in machine-readable text. This creates an opportunity to consider the relationship of clinical vocabularies to vocabularies used in scientific literature and the MeSH vocabulary.

NLM's experience and leadership in development of the MEDLARS system and the MeSH vocabulary are enormously valuable as a foundation for undertaking development of a Unified Medical Language System. The insights and experiences that have been generated in the Library's previous work can offer a sound foundation for extending the concept of a controlled vocabulary into other areas.

Impediments

A common language must be derived ultimately within a common conceptual framework. Reconciling existing frameworks will be difficult; accommodating the language from those disciplines that have not yet identified a common framework will make this task even more difficult.

The language developed in specialized areas is resistant to change by outside pressures. The proposed development of a unified language requires a major collaborative project among NLM, the different professional societies, academic organizations, professional boards, credentialing and licensing boards, reimbursement agencies, editors of professional journals, and relevant Government agencies. Collaboration on this scale will be very difficult to orchestrate. Each group and subgroup will have interests to protect, both professional and financial. Those who have invested

the most in prior standardization may have the most to lose. Many clinicians will display inertia and overt resistance to changing long-standing habits of expression. The need for international interchange of information adds to the complexity. The utmost dedication, imagination, and leadership on the part of NLM will be required.

Centers of Excellence in Health Sciences Informatics

Current Situation and Needs
Informatics in the health sciences is a developing field of applied science that has made admirable progress in the past decade. A major factor in this progress is related to the leadership of NLM and a few individual academic laboratories (often sponsored by NLM research grants). In addition, private industry has become more aggressive in developing and marketing information technology support systems, such as those for hospital information, bibliographic reference, electrocardiographic analysis, and the like. However, the promise of information technology in medical applications has only begun to be tapped. There is a pressing need to support and promote work in this field.

Many of the significant advances in medical informatics have come about in combined academic/clinical environments characterized by a combination of administrative support, substantial stable funding, and expert human resources. Such environments, however, are unusual. Many of these units have evolved more as a result of the combination of the

individual initiative of a few creative individuals and fortuitous circumstances, rather than planning. In order to promote more rapid advancement in the field of medical informatics, well-planned centers of excellence for research and training are needed. These will provide the necessary combination of academic/clinical environments, stable material resources, and concentrated expertise.

Windows of Opportunity
Health science informatics is attracting many bright young individuals from the health and engineering professions, as well as from medical library science and academic administration, who have the potential to advance the field. Without advanced training and opportunities for research, this talent pool will probably not be tapped to its full potential. Establishing centers of excellence would enable the Nation to develop and expand a highly skilled cadre of researchers in informatics for all the health specialties; the centers would provide long-term career support and job opportunities in order to keep talented individuals in this highly important field.

Several of the IAIMS projects, as well as other existing centers (including NLM's own Lister Hill National Center for Biomedical Communications), can serve as models for the centers needed in health professional schools and teaching hospitals. In addition, there are currently a number of health professionals who, by virtue of education and experience, have amassed considerable expertise in the application of computers to health-care problems. With appropriate funding, their expertise might be tapped for these centers to further research and training in health science informatics.

Establishing centers of excellence may be the most rapid and effective means of promoting medical informatics in this Nation. Such centers will provide a highly visible critical mass of individuals, capable of exploiting and expanding computer technology for the ultimate goal of high-quality, cost-effective education and health care.

Impediments

A major impediment to establishing centers of excellence is the requirement of long-term, stable support. NLM must have sufficient funds and an appropriate funding mechanism to provide such support.

Since the expected outcomes of this project may not be realized for several years, it will be critical to select for initial funding those institutions that have high potential for producing results. The requirements should include demonstrated leadership, a well-documented track record of accomplishments, an obvious potential for continuing excellence, and the unambiguous support of the local administration. There are only a few institutions at present that meet these criteria. There is, therefore, a need to promote this concept and to encourage schools to develop their resources so that they may compete for these awards.

There are several major reasons to provide a high level of stable support for the proposed centers of excellence. Such funds would encourage the evolution of institutional role models for the field and also support the development of applications in medical informatics that can be readily disseminated. In addition, a fundamental component of the center concept is a high level of collaboration among different institutions. However, there is no strong precedent for the dissemination of computer applications in medical informatics, and true institutional collaboration is rare.

NLM must develop review and funding mechanisms that foster such an attitude and, in addition, NLM will need to maintain close surveillance of the centers and implement an evaluation program that measures performance in terms of institutional acceptance and support. At the same time, performance would be assessed in part by the extent of collaboration and successful dissemination.

Knowledge-Management Systems for Practicing Health-Care Professionals and Students

Current Situation and Needs

There is general acceptance of the claim that practicing health professionals could benefit from greater accessibility to current information about optimal diagnostic and treatment strategies and appropriate therapy. However, few specific data are available on the details and frequency of the clinical problems and the decisions that a health-care provider is required to make in the course of his or her daily practice. Even less is known about whether, and to what extent, better accessibility of relevant information would improve the quality of health care or make its delivery more cost-effective.

Descriptive research is needed to delineate the information needs of the practitioner in various settings. Demonstration projects are required to gain experience in utilizing computer technology in knowledge-management systems that guide and serve the practitioner. Evaluative research is needed to determine the utility and effectiveness of these systems in clinical practice.

A knowledge-management system should be tightly linked with a computer-based medical record system so that the information activities of clinical practice can be integrated with decision support and continuing education. This requires a well-designed interactive computer system that would both support routine information-handling needs and provide ready access to appropriate knowledge bases (e.g., drug information data bases, data bases on appropriate use of specific tests, information on effective diagnostic strategies, etc.).

A knowledge-management system has the potential to integrate clinical records with quality-assessment and quality-assurance activities that are fully under the control of the user. There is a pressing need for clinical information systems that allow the systematic analysis of practice patterns. Such a system should be capable of providing feedback and reminding the user when he or she deviates from predefined quality-assurance protocols. To gain the full support and participation of individual practitioners in this activity, it will be important to assure each one that feedback on individual performance will be provided confidentially, as a learning experience. Care should be taken to assure them that this activity is in no way perceived as one with punitive implications.

A knowledge-management system should support the following uses:

- Targeted Information Retrieval. This is the mode in which a user seeks to retrieve knowledge to support a specific problem-solving task. As was pointed out in a recent study of physician needs for information in office practice,[13] problems frequently occur in daily practice that require information that is not usually provided by available print sources. Not only is such knowledge retrieval important for making the decision itself, but learning tends to occur best in a problem-solving context, i.e., when the need for information is urgent.

- Browsing Knowledge Retrieval. This is the mode in which the user is interested in how a particular fact relates to other facts and is attempting to learn more about the context of a particular issue in order to understand more about it. The equivalent function in using a book is scanning adjacent paragraphs or looking through the table of contents. For example, if the user of the knowledge-management system were looking up the side effects of a particular drug used to treat hypertension, the user might also be interested in other facts about the drug, e.g., the pharmacologic class to which it belongs or its mode of action.

- Decision Support. A knowledge-management system developed with assistance from professional societies should help in identifying the data that are critical for a particular clinical situation. For example, clinical data bases can be developed that would provide such important information as the recommended work-up for a specific clinical problem or the predictive value of specific signs, symptoms, and laboratory tests. Nursing research, for instance, shows that nurses often "lack effective cognitive strategies for processing data."[14]

- Personal Reference System. The conceptual framework used in a knowledge-management system will usually be devised by experts. This will provide a logical schema for filing observations that reflect the user's own unique combination of concerns and a personally selected bibliography.

- Topic-Specific Bulletin Boards. The conceptual framework of the knowledge-management systems can likewise serve as the organizing principle for informal, topic-specific bulletin boards. Users with targeted interests

could inquire about (or add information on) research in progress, preliminary findings, generalizations from clinical experiences, or specific clinical or management topics. This would significantly extend to a much wider community the existing practice of consulting with peers on problems or topics of interest.

Two overriding design considerations are that the knowledge-management systems (a) be affordable by both the self-employed health-care practitioner and by organizations that employ health-care practitioners, and (b) be relatively simple to access and use.

Windows of Opportunity

The increasing complexity of medical care, the continuing knowledge explosion, and the importance of considering costs in diagnostic and therapeutic decisions make it more necessary than ever for health-care providers to access and utilize the most current and reliable information in making decisions about their patients. Health-care practitioners are becoming increasingly aware that they cannot rely on memory alone; they need the ability to obtain problem-specific knowledge, to appraise it critically, and to utilize it appropriately. In medicine, the need for such orientation is one of the major tenets of the *Report of the Panel on the General Professional Education of the Physician and College Preparation for Medicine* (the GPEP Report) of the Association of American Medical Colleges,[15] and the report of the American Medical Association's Council on Medical Education, *Future Directions of Medical Education.*[16]

As an aid to both clinical decision making and education in the health professions, computer technology can play an important role in knowledge management and knowledge retrieval. The traditional role of NLM has been in the cataloging, storage, and indexing of paper documents. The availability of electronic storage of such information now offers a radically new opportunity for NLM to make clinical and scientific information much more available and accessible to the health-care professional. The mission of NLM can and should evolve from being primarily one of document storage to one of knowledge management.

Impediments

The design of useful knowledge-management systems for health-care providers depends in large part on three factors:

- the size, completeness, and quality of the knowledge bases available;
- the availability of effective tools to allow easy and timely access to appropriate portions of the knowledge base; and
- the implementation of appropriate methods of generating, updating, and controlling the quality of the information.

Creation of such knowledge bases will not proceed actively until there is reasonable expectation on the part of authors and software publishers that health-care practitioners will find computer-based knowledge-management systems attractive. On the other hand, practitioners will not be tempted to employ such systems until there is a critical mass of content, in terms of scope and inclusiveness, that is both available and easily accessible.

Furthermore, unless appropriate mechanisms are in place to assure confidentiality, individual users may perceive that the record of their performance could lead to punitive judgments by other parties. Whether real or wrongly perceived, this would greatly diminish the voluntary participation that will be needed.

A similar limitation is that administrators of health-care organizations and financial reimbursement agencies are unlikely to provide financial support for access to knowledge bases for health-care professionals until their impact on effectiveness of decision making and utilization of resources has been demonstrated.

Prototype, exploratory developments, and initial evaluation efforts are essential to overcome these barriers.

Educational Technology

Current Situation and Needs

Technology exists to provide students with a wide variety of tools and aids to learning, including computer-assisted instruction, computer-based simulations, word processing, bibliographic retrieval, self-testing and appraisal, electronic textbooks, personal file management, and electronic mail. Many professional schools currently make at least some of these tools available to their students, and increasingly students are acquiring personal hardware and software for facilitating schoolwork.

Enlightened educators and students sense the potential of this technology, but are frustrated because the current piecemeal approach prevents its full realization. They envision a curriculum where technology is fully integrated into all coursework, and where all faculty and students have access to similar, compatible resources. These educators also recognize the added flexibility that modern information technology provides to accommodate individual variations in interests, ways of learning, and uses to which knowledge is put. The vastly increased capacity to extract materials selectively tailored to a very special learning purpose from multiple sources allows much greater individualized use of curriculum content than could any set of standardized textbooks.

As the costs of higher education continue to rise, faculty productivity and effectiveness have become crucial issues. CMI (Computer-Managed Instruction) provides the technology to facilitate the administrative aspects of student progress through a curriculum. CMI can coordinate course objectives, maintain syllabuses and bibliographies, and keep track of course grades and evaluation notes. It can schedule students for courses, labs, and clinical practicum requirements in proper sequence. Its

promise as a technology for improving faculty productivity and efficiency should be further developed and evaluated for the complex requirements of education in the health sciences.

Windows of Opportunity

The Association of American Medical Colleges' Steering Committee on the Evaluation of Medical Information Science in Medical Education has concluded that advances in information technology applied to the educational process have progressed sufficiently for medical informatics to be an "obligatory component of modern medicine."[17] [18] Increasingly, health science educators recognize that it is important to provide the student with control over his or her education through the encouragement of personal initiative, self-directed learning, and frequent opportunity for self-assessment. Students are generally comfortable in using the computer and react positively to its use in instruction. Schools in the near future will probably require students to acquire computer equipment, just as they now require microscopes and stethoscopes; at the same time, many students will enter professional training with considerable experience gained from elementary, high-school, and college computer courses.

The introduction of computer-based testing by the National Board of Medical Examiners in 1988—initially in the Part III examination and subsequently in the Part I and II examinations, as well as the Federation Licensing Examination—will provide a significant impetus to students and medical schools to utilize advanced technologies in educational settings. This initiative will have a profound impact in the United States, since every physician licensed to practice medicine in this country is evaluated by an examination developed or prepared by the National Board of Medical Examiners.

Increasingly sophisticated students and instructors will be able to take advantage of expanded technological capabilities, such as interactive video disk, animated graphics, physiological and epidemiological modeling programs, and networked student/faculty workstations.

The comprehensive use of information technology in the education of health professionals can have far-reaching effects. The student who uses the computer as an indispensable tool during the formative educational years will undoubtedly find it an indispensable partner in future practice.

Impediments

As is true in other developing fields, a lack of standardization in educational technology inhibits the sharing of materials and methods. Indeed, a built-in conflict exists between the goals of developing exciting and stimulating prototypes and the standardization of methods.

Efforts to standardize professional curricula or resources have not met with great success. Only minimal progress has been achieved in standardizing computer equipment and software.

In the case of computer programs relevant to educational technology, standardization is inhibited by the inertia of the many and diverse users who cannot individually justify conversion to a standard that arrives after they have invested their scarce resources in their own application programs on their unique operating systems. In only a few situations are programs available that allow conversion of old systems to new systems without extraordinary cost.

Faculty efforts to develop and use educational technology are fragmented and insufficiently supported either by local institutions or external funding. This limitation is particularly true with regard to the development of computer-based materials, since such activity is very time-consuming and is rarely considered a research contribution. In addition, publications in educational or information technology journals do not offer the same recognition for promotion purposes as do papers in traditional research journals.

A number of health science schools have developed audiovisual departments with varying success. However, only rarely will an institutional organization already in place assist with the development of computer-assisted instructional software. At any given school individual faculty members maybe interested in this activity, but even so, the development is often fragmented, with little overall plan, integration of either software or hardware, or sharing of resources or support personnel.

Similarly, there is no comprehensive cataloging of instructional software, and very little interchange of materials from one institution to another or indeed, even among disciplines within a single institution. An example of what is needed to remedy this is *Patient Management Simulations: A Resource Catalog,* recently produced by the Office of Educational Resources and Research of the University of Michigan Medical Center.[19] Based on a national survey, it lists information about more than 70 simulations from 64 sources. Another example is the *Index to Computer-Based Applications in Dental Education,* published by the American Association of Dental Schools.[20]

The effectiveness and cost-benefit of new educational technology in the health sciences have not been clearly demonstrated. Such evaluation is very important, but it is difficult because of our very limited ability to measure the effectiveness of current educational methods.

Recommendations

Unified Medical Language System

We Recommend That NLM Support Development and Use of a Unified Language For All the of the Health Sciences

More specifically, NLM should do the following:

(1) Sponsor a consensus-seeking conference and subsequent periodic working conferences that would bring together representatives from all appropriate concerned sectors for joint consideration of the problems involved in the development, dissemination, and utilization of a unified language system for the health sciences. Representatives of professional societies and licensing organizations in all areas of health care should be involved, as should representatives of the insurance industry, relevant Government agencies, and publishers of literature and software oriented toward the health-care community.

(2) Use the extensive experience of MeSH development and usage to begin at once to develop extensions of MeSH to index health system clinical information and provide nomenclatures for health professions other than medicine. Furthermore, NLM should continue to identify new terms and relationships between terms by automatic monitoring of the full text of citations stored in the NLM computer-stored data bank.

(3) Investigate as an intramural project the relationships between the vocabulary used in MeSH and word usage in the test question banks of the different certification organizations (e.g., the National Board of Medical Examiners and the various medical specialty and subspecialty boards.) NLM should also apply this process to question banks developed by credentialing boards in other health professions in order to provide direction for both expanding MeSH and developing the Unified Medical Language.

(4) Develop collaborative efforts with specialty societies and other health professions to extend the MeSH thesaurus into clinical care records, connecting terms used in these fields to broader, narrower, and related terms in the existing thesaurus. Professional societies in all areas of health care should be involved, as should representatives of the insurance industry, relevant Government agencies, and editors and publishers of literature and software oriented toward the health-care community.

(5) Promote and support extramural projects that focus on the use of a Unified Medical Language in interactive, computer-based clinical information systems. NLM should give a high priority to gaining experience with such standardized vocabularies in operational medical information systems used in a variety of settings by the full spectrum of health professionals.

(6) Support extramural projects to develop standard vocabularies modeled on MeSH. These vocabularies must take into account the specific concerns of the various health disciplines and the subspecialties. The necessary support utilities must be developed, (e.g., dictionaries of terms, a thesaurus, cross-indices, automatic classification and indexing assistance tools, and computer programs to validate the literature and medical records that use the vocabulary). This should be followed by automated indexing and classification of clinical records and literature by these standard terms.

(7) Encourage the development of computer-based instructional programs that utilize the Unified Medical Language. The Panel strongly believes that it is essential to inculcate in the health science student from the start the need for and usefulness of a common language. We further recommend that NLM provide financial start-up support for model educational programs that include a major focus on the use of a uniform vocabulary.

(8) Undertake and sustain long-term initiatives and collaborative efforts to promote the use of the Unified Medical Language by editors and publishers of journals, books, computer programs, and other media produced for health professionals.

(9) Promote and support both intramural and extramural projects that explore and develop effective methods of knowledge retrieval from full text.

Centers of Excellence

We Recommend that NLM Establish Centers of Excellence For Research and Training in Medical Informatics Technology as Applied to the Health Sciences.

These centers of excellence should have the following characteristics:

(1) Each center of excellence should have a strong research focus and significant educational and training components. In addition, each center should be a leader in introducing information technology into health professions education and in stimulating the introduction of health science informatics content in the curricula of the different professional schools.

(2) Each center of excellence should incorporate a true multidisciplinary approach. In particular, each center should develop a substantial relationship with the operational health delivery system, practicing professionals from all health disciplines, and the health science library community. The geographical location of a center, although important, is not as critical as that a proposed center provide a core of educational, technological, and research resources that will have an impact beyond the local area.

(3) In each center, NLM should support training of highly skilled career investigators, provide adequate core research funding, and support career development programs for experienced researchers (including individuals visiting from non-center institutions.)

(4) Additional criteria for an award should be a willingness of the proposed center to collaborate with other center awardees in a consortium arrangement so that each center can benefit by and build upon each other's experience. One of the most important criteria is the proposed center's capacity to aid in disseminating its accomplishments and contributions to other professional schools and the practicing health professional—locally, regionally, and nationally.

(5) Funding of a center should be for a minimum 5-year period, at a level of approximately $1 million each year for each center. This is needed to fulfill the training and dissemination functions and provide the necessary commitment to build and support a center's research infrastructure and ensure continuity for productive research and development.

(6) Funding would support staff resources and core project activities. Each center would also compete, along with other investigators not affiliated with a center, for the available funds NLM has in its budget base to conduct additional investigator-initiated research projects outside of the center's core research. Center-based investigators would of course be encouraged to seek funds from other Federal and private sources.

(7) In order to assure productive outcomes, a number of preconditions should be met by the applicant institutions/organizations. These should include evidence of administrative support and support of academic leadership, a minimum required level of salary support commitment by the institution, pre-existing resources such as computer equipment and space, a core staff who has demonstrated previous achievements in medical informatics, evidence of support for the conversion of the institution's library into an information-management center able to participate fully in medical informatics programs, and evidence of the willingness of the curriculum committees to integrate training in medical informatics with other parts of the professional curriculum.

Knowledge-Management Systems

We Recommend That NLM Develop an Extramural Research Support Program For Development, Use and Evaluation of Prototype Knowledge-Management Systems.

More specifically, NLM should:

(1) Stimulate the development of functioning prototype knowledge-management systems and make them available to selected users; gain experience with the use of these prototypes; and obtain feedback about problems, limitations, and needed capabilities. These systems should be designed to be used directly by health professionals in daily practice and should integrate routine clinical information processing with knowledge retrieval. In addition to scientific medical knowledge, information that instructs the health professional on how to gain access to community resources (e.g., extended care facilities) should be included. They should include user-interface methods and tools to facilitate targeted knowledge retrieval, browsing, and decision support. In addition, NLM should seek to establish collaboration with Federal reimbursement agencies and private health insurance companies to establish mechanisms so that agencies could share the costs of developing operational prototypes from which they would directly or indirectly benefit.

(2) Undertake programs that would lead to a critical mass of content for inclusion in a knowledge-management system. As part of the effort to evaluate quality of content, NLM should undertake to establish active collaboration with other organizations, particularly professional societies and credentialing, licensing, and reviewing boards, to develop mechanisms to support the acquisition and organization of the expert

knowledge base. NLM should also seek active collaboration with such organizations in studies directed at evaluating the dissemination and utilization of specific applications of knowledge-management systems.

(3) Fund research aimed at resolving potential problems and issues related to the development and maintenance of knowledge-management systems, including:

- improved understanding of the information-seeking behavior and the access needs of practicing health-care providers;
- consideration of the different behavior involved in targeted, problem-solving knowledge retrieval versus browsing versus decision support;
- development of alternative strategies for transforming information pertaining to health sciences into an "electronic textbook" format and consideration of mechanisms for content update and revision as needed;
- consideration of problems of individual versus communal authorship; and
- delineation of software engineering issues involved in computer storage and access of large and complex health science knowledge bases.

(4) Support research aimed at determining to what extent a practice-linked, knowledge-management system could facilitate cost-effective decisions and more judicious use of available resources.

Educational Technology

We Recommend That NLM Undertake a Series of Projects Aimed at Developing Educational Applications of Computer Technology and Integrating These Applications Into Health Sciences Curricula.

More specifically, NLM should:

(1) Support development of novel forms of applications of information technology that have the potential for significant educational impact. Possible examples include:

- the use of computer models that can interact with the student in a consultative or explanatory fashion;
- programs that provide realistic simulations of patient cases that could help the student learn about diseases that might not be encountered in his or her clinical rotations; and
- simulations of physiological systems that provide students the opportunity of learning the interactions and feedback that exist among biological variables in complex systems.

(2) Promote access to computer-based educational resources by undertaking the following:

- publicize the availability of resources that have been cataloged;
- support improvements to the National Learning Demonstration Center as a location where visiting scholars can explore existing materials in a variety of health-related subject areas and use various computer and video educational technologies;
- support the development of extramural demonstration centers where faculty can observe and use computer-based educational applications;

- promote increased awareness among health sciences faculty and librarians about the use of educational technology by supporting training in medical informatics and by sponsoring fellowships. Such training would be an appropriate part of the proposed centers of excellence program; and
- support annual conferences, "tradeshows," seminars, and demonstrations where the new developments in educational applications of information technology can be reviewed and evaluated by invited decision-makers in medical education.

(3) Seek external consultation about how to promote the development of "standardized" authoring languages and programming tool kits to facilitate national dissemination. An analysis of existing tools should be undertaken. These languages and tool kits would enable the production of educational software at a sufficiently high level of abstraction to match different educational philosophies and specific technologies.

(4) Explore the adaptation of computer-based methods developed by the National Board of Medical Examiners. Although developed for testing purposes, these simulations demonstrate strategies that can be usefully modified to meet instructional needs of individual schools of medicine.

(5) Develop mechanisms for specific review and documentation of the available educational software, as well as a system of cataloging transferable programs. This software should be indexed in the appropriate health science indexes (*Index Medicus, Cumulative Index to Nursing and Allied Health Literature,* etc.) so that it is as accessible as journal articles.

(6) Promote the publication of reviews of computer-based educational programs by professional journals. NLM should work with appropriate professional societies to develop techniques and standards for review of computer-based programs.

(7) Initiate, promote, and support collaboration with professional societies in developing lists of topics to be taught in specific subject areas. These topic-area lists would serve as a guide to indexing of materials and for developing new computer-based educational materials.

(8) Work through the Regional Medical Libraries to advance and coordinate utilization of new technologies as they become available. The professional staff of the Regional Medical Libraries would be trained to provide an interface between potential users of technology and the NLM resources that might facilitate such use.

(9) Support the development of model curricula where information technology is fully integrated into the design, management, and delivery of a particular health science educational area.

- Accredited schools in the various health sciences would be eligible to apply for grants for planning, implementation, and evaluation of the proposed curriculum. NLM should assure representation of the major health professions in a model curriculum project.
- NLM should provide support for faculty time devoted to integrating computer technology into coursework, including development of course-related instructional programs where needed. Support should also be provided for the acquisition of hardware and software and for preparation of the academic health sciences library to serve as a participating unit.

- Applicant institutions would be selected based on the following: (1) prior accomplishments in the field of computer-based education and/or computer-managed instruction; (2) evidence of administrative support, including necessary changes to the institution's library; (3) allocation of space and existing hardware; and (4) evidence of collaborative arrangements with recognized experts in the field of computer-aided education.
- At the end of a specified period, independent evaluative studies should be carried out to gauge the effectiveness and impact of the curricula on student learning and faculty productivity and efficiency.

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Appendix A:
NLM Planning Process

In January, 1985 the Board of Regents of the National Library of Medicine resolved to develop a long range plan to guide the Library in wisely using its human, physical, and financial resources to fulfill its mission. The Board recognized the need for a well-formulated plan because of rapidly evolving information technology, continued growth in the literature of biomedicine, and the need to make informed choices of intermediate objectives that would lead NLM toward its strategic, long range goals. Not only would a good plan generate goals and checkpoints for management, actually a map of program directions, but it would also inform the various constituencies among the Library's users about the future it sought and could help to enlist their support in achieving that future.

At the Board's direction, a broadly based process was begun involving the participation of librarians, physicians, nurses, and other health professionals; biomedical scientists; computer scientists; and others whose interests are intertwined with the Library's. A total of 77 experts in various fields accepted invitations to serve on one of the five planning panels. Each panel addressed the future in one of the five domains that encompass NLM's current programs and activities. The domains, which provided the panels, a framework for thinking about the future are:

1. Building and organizing the Library's collection

2. Locating and gaining access to medical and scientific literature

3. Obtaining factual information from data bases

4. Medical informatics

5. Assisting health professions education through information technology

The Library chose a planning model with three components. First, it incorporates a general, somewhat indistinct vision of the future 20 years from now in medicine, library and information science, and computer-communications technology. That environment cannot be forecast precisely, but we can speak of a "distant" goal. That goal is seen as a societal objective whose attainment involves many organizations and agencies. NLM has a major role to play in achieving the goal and must plan its part. Second, while the 20-year goals are indistinct, there are opportunities for and impediments to achieving them. The opportunities and impediments can be more clearly envisioned because they appear to lie roughly 10 years away. Third, the specific steps that should be taken to remove the impediments and take advantage of the opportunities should be programmed for 3 to 5 years.

The planning process also involved participation within the Library. The Director provided his version of the future in the form of a "Scenario: 2005," which was distributed to panel members and Library staff. NLM staff prepared background documents that reported NLM achievements in the five domains, and reviewed current planning. Senior NLM staff members also acted as resource persons to the planning panels.

At the end of the planning process, each panel formulated recommendations and priorities for future NLM programs and activities in the domain under its purview. The five panel reports were reviewed by the Board of Regents in June 1986. The Board then asked the NLM staff to analyze and reconcile their findings, eliminating any duplications and consolidating the recommendations. Together with the planning panel reports, this synthesized plan presents the official Long Range Plan of the Board of Regents of the National Library of Medicine.

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